

# **DESIGN, IMPLEMENTATION AND EXECUTION RESULTS FOR SIMULATIONS AND C2 INFORMATION SYSTEMS CONNECTIVITY EXPERIMENTS (SINCE) EXPERIMENT 2**

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## **ABSTRACT**

In this paper we describe the design, implementation, and execution results obtained from the SINCE experiment 2b (SINCEx2b) which took place 17-28 July, 2006 at the Fort Dix facility of the NJ Army National Guard. The objective of SINCE is to conduct R&D experimentation in support of net-centric battle command interoperability and collaboration. The primary approach of this experiment is to build upon the success of the previous SINCE experiments by more than doubling the complexity of the scenario, the breadth and depth of information exchanges as well as the number of federates and interfaces. The number of coalition partners has also increased from two to five. An integral part of the solution is the establishment and refinement of a methodology by which the various information architectures would be harmonized within federations and across federations. The infrastructure for SINCEx2 is embodied in Proxy Servers and the Coalition Portal as federates that collectively include the various adapters and filters that mediate between the otherwise incompatible heterogeneous interfaces inherent in the selected federate systems using a common digitized Operations Order (OPORD) oriented model encoded as an XML schema. A significant contribution of SINCEx2b is to demonstrate an R&D-oriented, backwards compatible, common information model which supports and extends the C2IEDM and provides a “one-to-many” mapping to bridge across several disparate information architectures inherent in the applications and data models pre-existing in the various federates required by the operational user.

## **1. OBJECTIVE**

The objectives of SINCE is to promote experimentation in Net-Centric Battle Command Interoperability and Collaboration at an early stage of R&D before various

constraints are imposed that make it difficult to make fundamental changes in the approach or design. Thus the R&D experimentation is conducted in a mixed Technology Readiness Level (TRL) environment of loosely coupled 6.1, 6.2, 6.3, and 6.4 prototypes, C2 architectures and applications dynamically stimulated by combat M&S. The scenario may range from tactical to strategic objectives, include combat, combat support and combat service support units and tasks involved in low to high intensity conflicts spanning linear unpopulated areas to non-linear densely populated battlefields.

In this paper we describe the SINCE approach and provide initial results and insight on reaching steady state and transient phenomena associated with collaborative planning and situation awareness and understanding obtained from the second experiment. Multinational issues are addressed from both technical as well as operational perspectives which are then integrated. Multinational issues impact national issues relevant to Battle Command and therefore they need to be addressed in an integrated approach as well. Specific issues addressed in SINCE involve

- (a) Automating the federation process which includes data initialization among heterogeneous multinational and national C2 systems and modeling and simulation (M&S) systems as a federation of federations, and
- (b) Conducting multinational, multi-spectrum, multi-modal, multi-echelon, multi-session collaborative planning continuously under the stress of execution monitoring and maintaining a multinational Common Operational Picture (mCOP) in addition to a national nCOP.
- (c) Establishing an open Testbed for experimentation to enable measures of performance and assessments of new technology prototypes embracing Service-Oriented Architecture as well as interoperable frameworks of multi-Agent systems.

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## 2. INTRODUCTION

C2 systems support the user via four key technology areas: messaging, display, storage or decision support processing. To support interoperability, C2 systems implement various standards such as VMF, USMTF, ADAT-P6 and MIP MEM for messaging, APP-6 or MIL-STD 2525b for display, CADM, C2IEDM, and MIP DEM for data bases, and HLA FOM for processing. It should not be taken for granted, however, neither that these implementations are complete, nor, more importantly, that they are complete to the same level of implementation among federates. Unless all federate C2 systems fully comply with each and every one of the selected standard, disconnects will occur in initialization (interconnection and federation) as well as in collaboration and interoperation. The SINCEx2b proved to be effective in identifying several such gaps and addressed how best to mitigate potential disconnects. A key means to resolving incompatibilities was the establishment of a Battle Book for all the scenario entities and an Interface Control Document (ICD) for the process of collaboration. The Battle Book proved to be critical in establishing a mapping between the scenario entities and all attributes and their representations in accordance with the standards. We have found that implementation gaps exist due to the maturity of the system as well as the relative priority of implementing the entities and attributes identified in the standards. This brought to light an important insight with respect to assessing Technology Readiness Levels (TRL) of C2 Systems. The TRL is often assessed with respect to the maturity of the implemented functionality and not with respect to how much of the functionality expressed in the standard has been implemented. It is important therefore to establish a complementary maturity measure such as Implementation Completeness Level (ICL) which cites a reference standard or a specification and addresses completeness with respect to the implemented reference. This is key to the net-centricity of initialization, collaboration and interoperation.

Net-Centric Operations require net-centricity to be incorporated in all phases of the Information Exchange Process (Interconnection, Federation, Collaboration and Interoperation). The Interconnection Phase involves establishing the transport mechanism and configuring the nodes to support network management. Although network management was not addressed in this experiment, this phase is critical to establish who is available and ready for the operational run to proceed with the domain data initialization. During the course of an operation or an experimental run, a federate node may crash, a federate application may quit, or users may log off. This phase of the IER process maintains awareness of the participant status.

The user domain data initialization was implemented in accordance with the Battle Book. The Battle Book provided the common user domain data derived from the intersection of the entities and attributes identified in a) the operational scenario, b) the standards invoked by the C2 and M&S systems and c) the C2 and M&S system implementations. A Table and a Chart from the Battle Book are depicted in Table 1 and Figure 2, respectively. The scenario chosen by the SINCE Operational Working Group (OWG) is relevant to most current conflicts but is scaled down to address a limited set of operational issues. For example not all coalition partners may be NATO countries. This requires the architecture to be flexible to accommodate a variety of C2 Systems and C2 standards. Each nation has different responsibilities and strengths that may be leveraged. In addition each nation has different rules on what their soldiers can and cannot do. The level of experience, training, and professionalism may vary as well. The scenario was composed of five functional vignettes that focused on deployment to the AOR, employment, medical evacuation, mine clearing and re-supply of ammo and fuel. The collaborative planning and execution monitoring interoperability become particularly challenging in a multinational environment because of potential “gaps” in understanding and reconciling cultural factors, language expressions, force structure compatibilities and equipment capabilities. As Shown in Figure 1 the scenario involved a Multinational Division Plan to secure an airport.

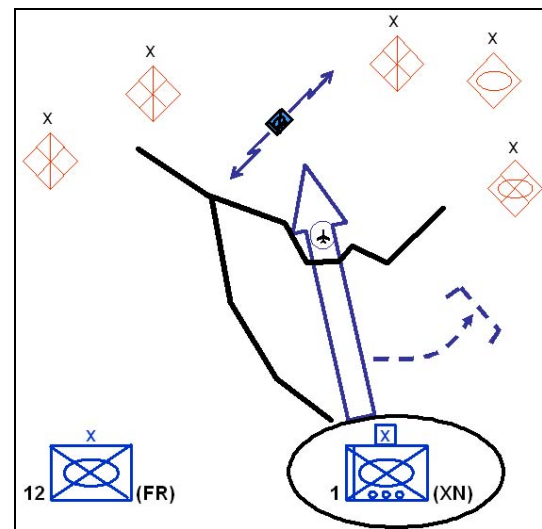


Figure 1. Scenario at the start of the experiment

The SINCEx2b was not only an experiment but an experiment in how to conduct experiments with C2 Systems. There are many ideas and suggestions on how best to improve C2. For each proposal there corresponds a set of hypotheses. Hypotheses that are proven to be true become “facts.” Hypotheses that are proven to be false become “myths.” Typically, hypotheses arise with

respect to competing attributes which require tradeoffs. Hypotheses investigated in the SINCE Program include the following type of tradeoffs: Integration versus Modularity, Functionality versus Performance, Computation versus Communications, Standardization versus Mediation, Information Assurance versus

Information Sharing, Scalability versus Complexity, and Constructive Simulation Versus Live Simulation.

FXN0011	1 BCT(XN)	1st BCT/Mech ID (XN)	BCT	IN/MECH/W/G
FXN0011000	HHC/1 BCT(XN)	HHC/1st BCT(XN)	CO	IN/MECH/W/G HQ
FDE001101	1(DE)/1	1st Mech BTF(DE)/1st BCT(XN)	BTF	IN/MECH
FXN001102	2(XN)/1	2nd Stryker BTF(XN)/1st BCT(XN)	BTF	IN/MECH
FDE001103	3 (DE)/1	3rd AR BTF(DE)/ 1st BCT(XN)	BTF	AR
FUS0011001	Mob(US)/1 BCT(XN)	EngMob Co(US)/1st BCT(XN)	CO	ENG/MOB
FUS0011002	AT(US)/1 BCT(XN)	AT Co(US)/1st BCT(XN)	CO	AT
FUS0011003	Mrt(US)/1 BCT(XN)	Mrt Co(US)/1st BCT(XN)	CO	MRT/MECH
FUS0011004	Med(US)/1 BCT(XN)	FwdSptMed Co(US)/1st BCT(XN)	CO	MED
FUS0011005	Sply(US)/1 BCT(XN)	Sply Co(US)/1st BCT(XN)	CO	SPL

Table 1. A tabular representation of the Task Organization (TO) of 1<sup>st</sup> BCT(XN)

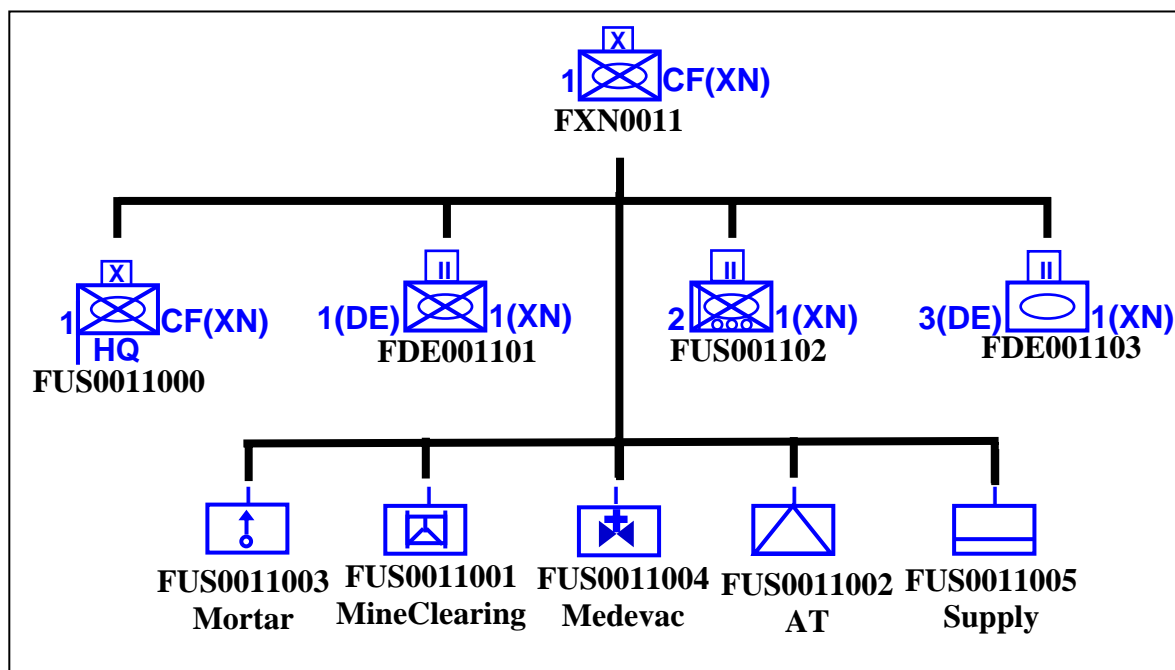


Figure 2. A graphical representation of the Task Organization (TO) of 1<sup>st</sup> BCT(XN)

The experimentation showed that a balance is needed among all of the above tradeoffs depending upon risk. Experimentation is an effective risk and cost reduction element of acquisition. But experimentation itself, especially in C2 can become very costly if not approached in a practical way. Experiments require an infrastructure and contractual vehicles that are synchronized. Information assurance must be enforced and international agreements must be in place to enable coalition partners to participate. A venue must be

secured and prepared and users must be made available. Prior to the actual conduct of the experiment, the technology must be developed and tested in a stand alone configuration with dummy inputs. Then, individual components need to be integrated and then again tested in an integrated environment such as available at Fort Monmouth CERDEC SINCE Lab. Only after, an application has passed the national integration tests is it ready for integration testing at the experimentation venue such as Fort Dix which involves operational users. Often

there are many variables that must be addressed. These variables are often interdependent and fall into two main dimensions: human and technology. The human dimension involves education, training and experience. The technology dimension involves human-friendly interfaces, processing time, aggregation, throughput and robustness.

The side benefits of conducting an experiment cannot be overstated. The experiment and all events leading up to the experiment provides a forum and a venue for users and developers to share ideas and to learn from each other. Negotiating on various aspects of the design of the experiment enables testing the flexibility of various designs of federates to adapt to new requirements. In addition, the wide diversity of disciplines involved in C2

systems provides an opportunity to integrate multi-disciplinary solutions leveraging human factors and computer programming. For example, Users may collaborate but may not really understand each other until an opportunity exists to provide an explanation. We therefore showed how an explanation system may complement the collaboration process to produce greater understanding of the plan. Another key side benefit is to expose the user to state-of-the-art future capabilities and to obtain feedback as to the viability of such capabilities in a standalone or integrated environments. Finally, the actual process of conducting the experiment produced interesting results that only became apparent as a byproduct without an a priori hypothesis.

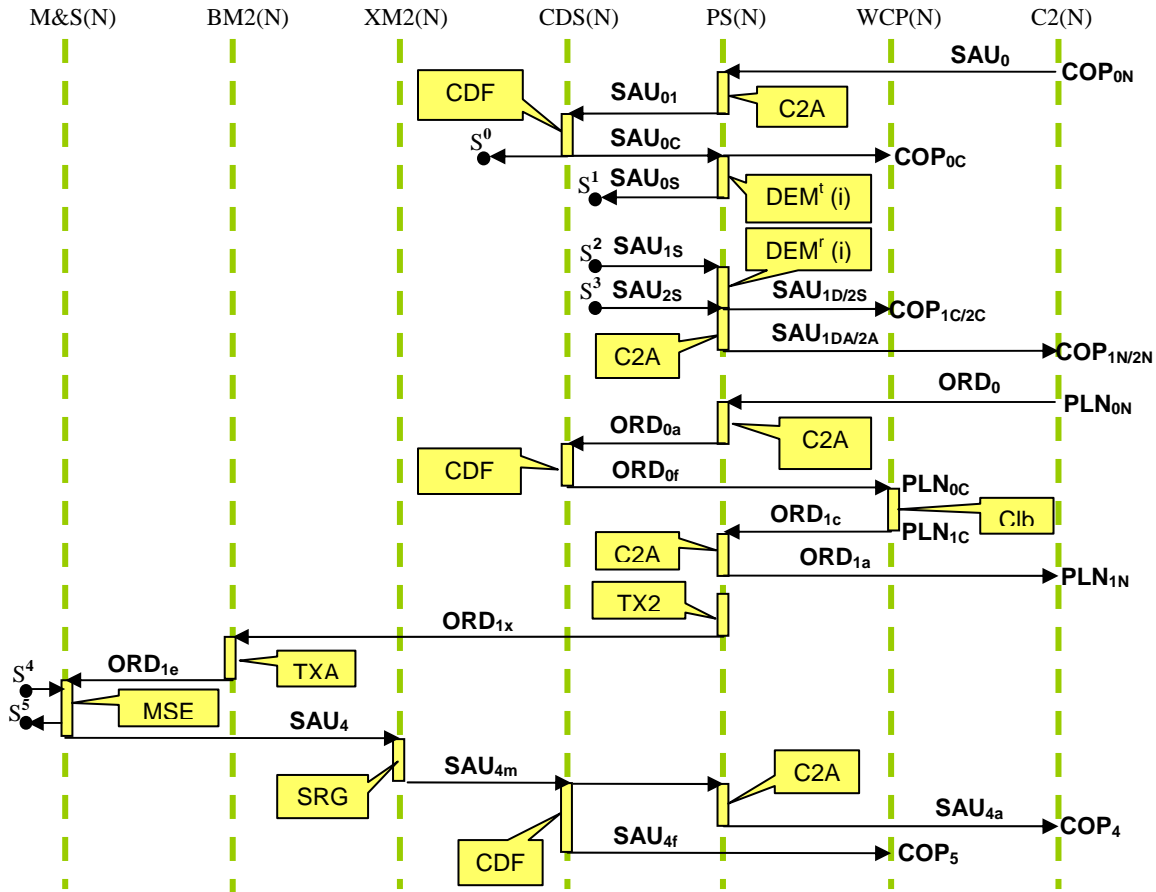


Figure 3. SINCEx2b Information Exchange Sequence View from a US perspective

The information exchange sequence from a US perspective is shown in Figure 3. In a three dimensional sequence diagram, Figure 3 would be replicated  $n$  times where  $n$  is the number of participating nations. The dots labeled  $S^0, 1, 2, 3, 4, 5 \dots$  represent multinational connections of various types.  $S^0$  and  $S^3$  represent an OPORD XML interface in accordance with the SINCE ICD using a Java Message System Data Exchange Mechanism (JMS

DEM).  $S^1$  and  $S^2$  represent the C2IEDM MIP DEM interface.  $S^4$  and  $S^5$  represent the HLA / DIS interfaces responsible for maintaining ground truth among entities interacting across constructive simulations. Figure 3 spans the collaboration and execution monitoring phases of information exchange process. Starting with the national C2 system's native Common Operational Picture (nCOP), bulk or incremental updates are issued

for all shareable situation awareness updates (SAU). This SAU is mediated by the Proxy Server (PS) C2 Adapter (C2A) to publish the common coalition SAU which gets filtered by the Cross Domain Solution (CDS) Cross Domain Filter (CDF) for sharing with the coalition partners. Coalition partners that can parse the common coalition SAU instances in accordance with the SINCE ICD can instantly update their coalition COP (cCOP.) This applies to wherever there is a Web C2 Portal (WCP). The PS(DEM<sup>1</sup>) distributes the SAU to the MIP DEM federates and reciprocally, at any time a MIP DEM compliant coalition partner may also send an update, which is processed via the PS(C2A) and sent to the national C2 system(C2(N)) to update the nCOP.

For the collaborative planning process again we start with the plans (PLN) generated by the C2 (N). Orders (ORD) that are relevant to the coalition are sent to the PS (C2A) to be represented in accordance with the OPORD XML schema. The CDS (CDF) ensures that the information is shareable and publishes the ORD on the MNC2 network for collaboration (Clb) by the WCP suite of tools: the graphical WCP, the Collaborative Workflow Tool (CWT) for scheduling, the Mission Notebook (MNB) for narrating, and C2Mate (C2M) for logging and generating an After Action Review (AAR). Once an ORD is transitioned from collaboration to execution, the Battle Management Mediator (BM2) Task eXecution eXtractor (TX2) identifies the tasks intended for the live or constructive simulated entities and provides them to the Task eXecution Assigner (TXA). The BM2(TXA) then schedules orders with the live or constructive simulated entities for execution at the appropriate time.

Immediately upon initialization, the live or constructive M&S(N) federates provide heartbeats that stimulate the generation of SAUs. Friendly SAUs are position reports which also include strength and readiness status as represented in Figure 4. Enemy SAUs are spot reports that are generated by friendly entities which are able to observe the enemy entities. SAUs that arrive at the eXecution Monitoring Mediator (XM2) are aggregated and delayed so as not to overload the network and unnecessarily interrupt the applications before they are reissued by the XM2(SRG) and published to the CDS(CDF) which will publish the shareable SAUs on the MNC2 in the common OPORD XML format.

### 3. DESIGN AND IMPLEMENTATION

Over fifty computers were interconnected via several distinct network domains as shown in Figure 5. These networked were bridged via computers with multi-port capabilities. Each nation had the option to establish its own national network. The US networks (USC2) networked the US Army Battle Command Systems

(ABCS) as well the live simulation capability being provided by the Secure Wireless Agent Technology (SWAT) tablet PCs and the gateway (SGW). The constructive simulators, MSUS and MSDE interoperating via HLA/DIS were networked via the Multinational Constructive Simulation network (MNCX). The Multinational collaboration and execution monitoring was accomplished via the Multinational C2 (MNC2) network. Finally the Multinational execution monitoring that took place using the MIP DEM was provided with a dedicated Multinational Monitoring (MNM) network as well.

```
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Figure 4. XML for Unit Strength and Readiness

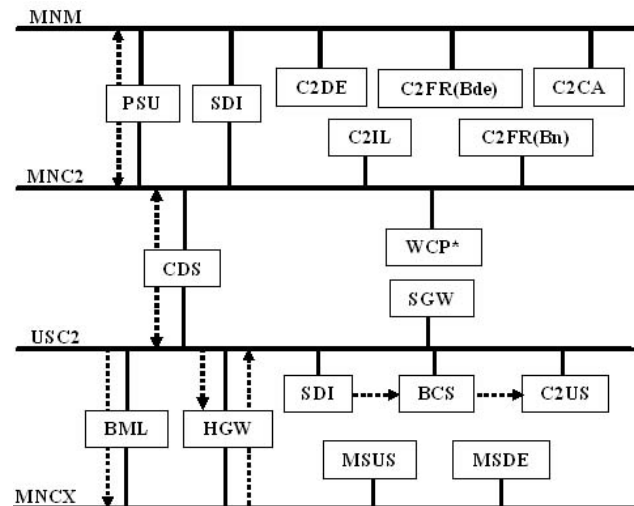


Figure 5. SINCEx2 US-Coalition Network Connectivity.



The US Proxy Server (PSU) and the Situation-Awareness Data Interoperability (SDI) gateways bridged between the MNM and MNC2 networks. The Cross Domain Solution (CDS) bridged between the USC2 and the MNC2 networks. The HLA Gateway (HGW) and the Battle Management Language (BML) bridged between the MNCX and the USC2 networks. The WCP\* refers to the set of Web portal tools including the graphics-oriented WCP, the MNB, the CWT, the CAT, and the C2M. The German Army C2 Systems (C2DE) were represented by Faust (FST) and HEROS (HRS). The German Army Modeling and Simulations (MS) systems (MSDE) included PABST and SIRA. The US Army MS system (MSUS) included three workstations of OneSAF Testbed (OTB) which shared the load of representing the US and allied units (FR, CA, and IL) tasked organized under the 2<sup>nd</sup> Stryker Battalion Task Force (SBTF) as well as the opposing Force (OPFOR). The US Army C2 Systems (C2US) were represented by the Combined Arms and Execution System / Mobile C2 (CAPES/MC2), Force Level Battle Command Brigade and Below (FBCB2) and the Joint web COP (JWC). The French Army C2 systems (FRC2) were represented by SICF and APLET at Brigade level and by Maestro art the Battalion level. The Canadian Army C2 system (CAC2) was represented by BattleView. Finally, the Israeli Army C2 system was represented by Beacon.

#### **4. EXECUTION RESULTS**

The architecture for experimentation proved to be highly flexible, scalable, and extensible. The M&S driven experimental environment was critical to technology assessment for potential transition. It enabled the testing of the interfaces under load and to stress the users as well with time critical events. We had no major difficulties in supporting two echelons (a brigade, and three battalions) for the live C2 cells and three echelons for live & constructive simulators (simulating companies, platoons, and platform entities). Workstations were provided for thirteen officers at the live C2 cells including a balanced mix of captains, majors, and lieutenant colonels from 5 Armies. The architecture accommodated interfaces to eight Multinational 'Systems of Record', twelve R&D prototypes, four constructive and one live simulation systems. The more than fifty PCs incorporated a wide range of technologies including a mix of intelligent agents and services arranged in peer-to-peer as well as client-server configurations. There was complete connectivity established among all PCs across ten bridged networks to allow greater information assurance and bandwidth de-confliction. Reflecting real world environments our architecture provided mediation at least among thirteen information exchange standards.

The Web C2 Portal (WCP) and associated applications for information sharing technologies were well received as key to a viable Multinational Force C2. They enabled integrated collaborative planning and execution monitoring using standard graphics and symbols for common understanding and shared vision. By exercising the software with many users the need to improve multi-user server performance, user logon, privileges and collaboration procedures became obvious. Having the user there was important to further define the details for such procedures.

Simulations proved to be essential in assessing performance of C2 Systems under load and of the users under stress. Constructive simulations are best suited to stress C2 systems with continuous traffic to force aggregation and filtering. Live Simulations proved invaluable in stressing the users with ad-hoc free-play injects to force re-planning. Again, having the user was important to further define the role of live simulations and how to make it more efficient with predefined templates for messaging.

The various prototypes were at different TRLs and as such it became a challenge to integrate and test them and to focus on their contribution and utility during the course of the experiment. As a result training the user in the use of the various prototypes and conducting excursions in running through the scenario, we identified integration issues associated with functionality, usability, scalability and extensibility to include considerations for coupling of multi-source, Mixed TRL R&D tools from Academia, SBIR, CERDEC, PEOC3T and PEO STRI. The data distribution response-time and throughput needed to be better controlled and managed along the information sequence. Currently the Proxy Server, MIP DEM, HLA Gateway, WCP need to create additional buffers to better manage interrupts and perform flow control that would prevent buffer overflows in recipient systems.

All developers benefited greatly from interacting with the users. This was especially true in the area of Human-Factors and Human-Machine Interfaces (HMI). Successful collaboration and exploitation of available tools depended upon proper training. The user only had a few hours of training before being asked to start using the tools. Most of the users were quick learners and started to navigate through the tools with little help. When the user was stuck, however, there was little or no help available through the HMI system because of the early nature of the prototypes. The loose-coupling of the tools is important to facilitate testing and integration but the ICD should include a display section that would facilitate the making of the transition across tools transparent to the user.

Assessing the performance of the user or of the various prototypes and systems of record was not one of the goals for this experiment but a great deal of insight was obtained in how one might deploy an AAR tool such as C2Mate to assess performance of the user as well as to assess the performance of the various C2 systems, the data distribution systems and the M&S Systems in a future experiment if such a goal were to be established. Certainly performance assessment must be provided as a function of the level of user training. Since we were dealing with highly structured data, information assurance compliance did not affect performance and the Cross-Domain Solution was able to keep up with effective sharing restrictions.

As we've learned from experiment 1 (Mayk et al, 2005), dealing with disparate terrain reasoning algorithms among C2 systems and M&S systems as well as across M&S systems meant that terrain representation and registration differences would require manual intervention to oversee and mediate the orders. This is a known issue that C2 experimenters are going to have to live with for a long time to come. Once routes were defined by the C2 systems, they almost always needed to be adjusted to the terrain available in the simulator. This suggests that to achieve the desired level of terrain de-confliction, terrain decision aids should be available in the C2 system that will use the terrain data available to the simulator to establish inter-visibility, traffic-ability and routes. One important feature of terrain based M&S is ground clamping. Since different simulators have different computational models for deriving elevation, it is not unusual for ground entities which are reflected or ghosted in another simulator to be above or below ground. We employed ground clamping to ensure that all ground entities when ghosted would have zero altitude. This is critical for mine fields and mine clearing operations as well as other type of fire interaction.

From a networking point of view, we observed that having separate nets bridged by gateways for M&S, for National C2 data, and for Coalition C2 was an important capability that alleviated congestion as well as improved information assurance. Messages were not lost due to lack of bandwidth. Information was lost however due to insufficient processing capabilities at the application level. We came to realize that on the Coalition C2 side, we must de-conflict interrupt-driven collaborative planning for a future OPORD from real-time execution monitoring of a current OPORD. Our web C2 portal server as currently designed could not keep up with continuously updating the SA while enabling the user to collaborate on an OPORD. As a result we had to time-multiplex manually between these two modes of C2. A solution is under development to be able to time-multiplex automatically via appropriate buffering and aggregation in a manner transparent to the user.

## 5. CONCLUSION

The SINCE Program achieved the project's objectives for Experiment 2 by successfully demonstrating improved connectivity, federation, collaboration and interoperability in a seamless process among coalition C2 systems, among coalition M&S systems and between a coalition of C2 systems and a coalition of M&S systems involving five countries. Important insights of both technical as well as operational nature were acquired to improve both design and implementation of future experiments as well as transition products. Furthermore, capabilities of both C2 and M&S systems that need further development were identified to enable future experiments to be conducted with more flexibility and in a more efficient and comprehensive fashion.

Overall, the US-DE-FR-CA-IL SINCE team considers the conduct of SINCE Experiment 2 a success. The program objectives were effectively addressed by leveraging existing (Current Force) and evolving (Future Force) C2 systems and prototypes as well as existing modeling and simulation systems and prototypes. While some technical integration problems were experienced that resulted from the increase in the scale of the test bed from SINCEx1b/SINCEx2a to SINCEx2b and the introduction of new capabilities in SINCEx2b (JUL 06, Fort Dix, NJ) above those tested out during SINCEx2a (SEP 05, Wildfleken, Germany), none of these problems was a "show-stopper" or of major issue. Future SINCE experimentation plans should be adjusted to allow more pre-experiment integration testing and training of the users both nationally and internationally to maximize the amount of operationally-oriented runs. There is little question that the experiment provided significant insight as to how to improve multinational collaboration and achieve semantic interoperability. The SINCE environment provides a cost-effective means to address the numerous issues and enable national, Joint and coalition partners to learn to better understand each other's "business rules", "business objects", concepts of operations, tactics, techniques and procedures.



## **6. ACKNOWLEDGEMENT**

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## **7. REFERENCES**

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